Eddy current

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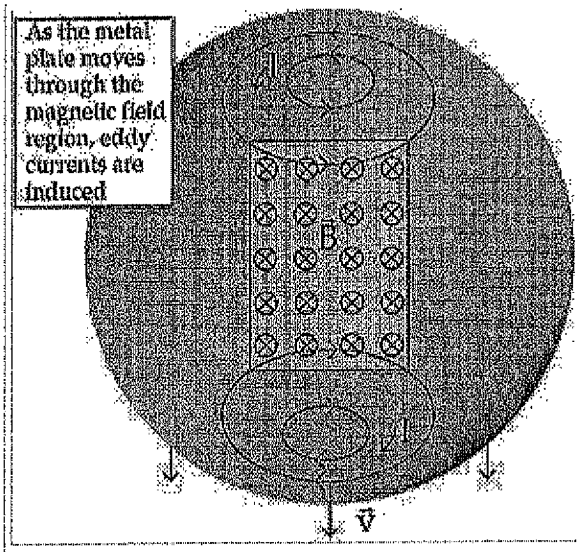
An **eddy current** (also known as **Foucault current**) is an electrical phenomenon discovered by French physicist Léon Foucault in 1851. It is caused when a moving (or changing) magnetic field intersects a conductor, or vice-versa. The relative motion causes a circulating flow of electrons, or current, within the conductor. These circulating eddies of current create electromagnets with magnetic fields that oppose the effect of the applied magnetic field (see Lenz's law). The stronger the applied magnetic field, or greater the electrical conductivity of the conductor, or greater the relative velocity of motion, the greater the currents developed and the greater the opposing field.



As the circular plate moves down through a small region of constant magnetic field directed into the page, eddy currents are induced in the plate. The direction of those currents is given by Lenz's law.

It is important to appreciate that eddy currents are created when a conductor moves across a constant, uniform magnetic field, as well as when a stationary conductor encounters a varying magnetic field. Both effects are present when a conductor moves through a varying magnetic field, as is the case at the top and bottom edges of the magnetised region shown in the diagram. Eddy currents will be present wherever the conducting object, which is moving, experiences a magnetic field, and not just at the boundaries. However, in some geometries, transient eddy currents can cause charges to collect on the extremities of the object and these charges then produce electric fields that oppose any further flow of current.

The swirling current set up in the conductor is due to electrons experiencing a Lorentz force that is perpendicular to their motion. Hence, they veer to their right, or left, depending on the direction of the applied field and whether the strength of the field is increasing or declining. The resistivity of the conductor acts to damp the amplitude of the eddy currents, as well as straighten their paths. Lenz's law encapsulates the fact that the current swirls in such a way as to create an induced magnetic field that opposes the phenomenon that created it. In the case of a constant, uniform applied field, the induced field will always be in the opposite direction to that applied. The same will be true when a varying external field is increasing in strength. However, when a varying field is falling in strength, the induced field will be in the same direction as that applied, in order to oppose the decline.

Eddy currents create losses through Joule heating. More accurately, eddy currents transform useful forms of energy, such as kinetic energy, into heat, which is generally much less useful. Hence they reduce the efficiency of many devices that use changing magnetic fields, such as iron-core transformers and electric motors. They are minimized by selecting magnetic core materials that have low electrical conductivity (eg ferrites) or by using thin sheets of magnetic material, known as laminations. Electrons cannot cross the insulating gap between the laminations and so are unable to circulate on wide arcs. Charges gather at the lamination boundaries, in a process analogous to the Hall effect, producing electric fields that oppose any further accumulation of charge and hence suppressing the flow of eddy currents. The shorter the distance between adjacent laminations (ie the greater the number of

laminations per unit area, perpendicular to the applied field), the greater the suppression of eddy currents.

The loss of useful energy is not always undesirable, however, as there are some practical applications. One is in the brakes of some trains. During braking, the metal wheels are exposed to a magnetic field from an electromagnet, generating eddy currents in the wheels. The eddy currents meet resistance as they flow through the metal, thus dissipating energy as heat, and this acts to slow the wheels down. The faster the wheels are spinning, the stronger the effect, meaning that as the train slows the braking force is reduced, producing a smooth stopping motion.

The term eddy current comes from analogous currents seen in water when dragging an oar: localised areas of turbulence known as *eddies* give rise to persistent vortices.

Contents

Applications

Electrical

Eddy currents are used to great effect in movement-to-electricity converters such as electrical generators and dynamic microphones. They can also be used to induce a magnetic field in aluminum cans, which allows them to be separated easily from other recyclables. Superconductors allow perfect, lossless conduction, which creates eddy currents that are equal and opposite to the external magnetic field, thus allowing magnetic levitation. For the same reason, the magnetic field inside a superconducting medium will be exactly zero, regardless of the external applied field.

Mechanical

Eddy currents are used for braking at the end of some roller coasters. This mechanism has no mechanical wear and produces a very precise braking force. Typically, heavy copper plates extending from the car are moved between pairs of very strong permanent magnets. Electrical resistance within the plates causes a dragging effect analogous to friction, which dissipates the kinetic energy of the car.

Structural Testing

Eddy current techniques are commonly used for the nondestructive examination (NDE) and condition monitoring of a large variety of metallic structures, including heat exchanger tubes, aircraft fuselage, and aircraft structural components.

Another eddy current technique for nondestructive testing was developed by Dr. Abdollah Abtahi using the Fourier transform method in 1981. This technique allowed small flaw detection in a large area much faster than any other technique. This method predicts very accurate results for small flaws in a large area. This method can be applied for testing any flaws in an airplane body/fuselage or a large satellite dish. This research was supported with a grant by the Electric Power Research Institute (EPRI).

Side Effects

Eddy currents are the root cause of the skin effect in conductors carrying AC current.

Links to Applications

- Electromagnetic brakes
- Metal detectors
- Induction cooker
- Traffic detection systems
- Mechanical speedometers
- Vending machines (detection of coins)
- Safety Hazard and defect detection applications
- Electric meters (Electromechanical Induction Meters)
- Displacement sensors
- Eddy-current testing
- Eddy current adjustable-speed drives
- Coating Thickness Measurements (https://www.fischer-technology.com)

References

- Fitzgerald, A. E.; Kingsley, Charles Jr. and Umans, Stephen D. (1983). *Electric Machinery*, 4th ed., Mc-Graw-Hill, Inc., page 20. ISBN 0-07-021145-0.
- Sears, Francis Weston; Zemansky, Mark W. (1955). *University Physics*, 2nd ed., Reading, MA: Addison-Wesley, pages 616-618.

External links

- A video demonstration of Eddy currents (http://video.google.com/videoplay?docid=1660843971041561797&q=neodymium&hl=en)
- The Eddy Current Loss Anomaly (http://www.energyscience.org.uk/le/le18.htm)

See Also

- Eddy current testing world wide (http://www.dci-meettechniek.nl)

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